A Phenomenological Study of Contamination Enhanced Laser-Induced Damage in Sealed Lasers

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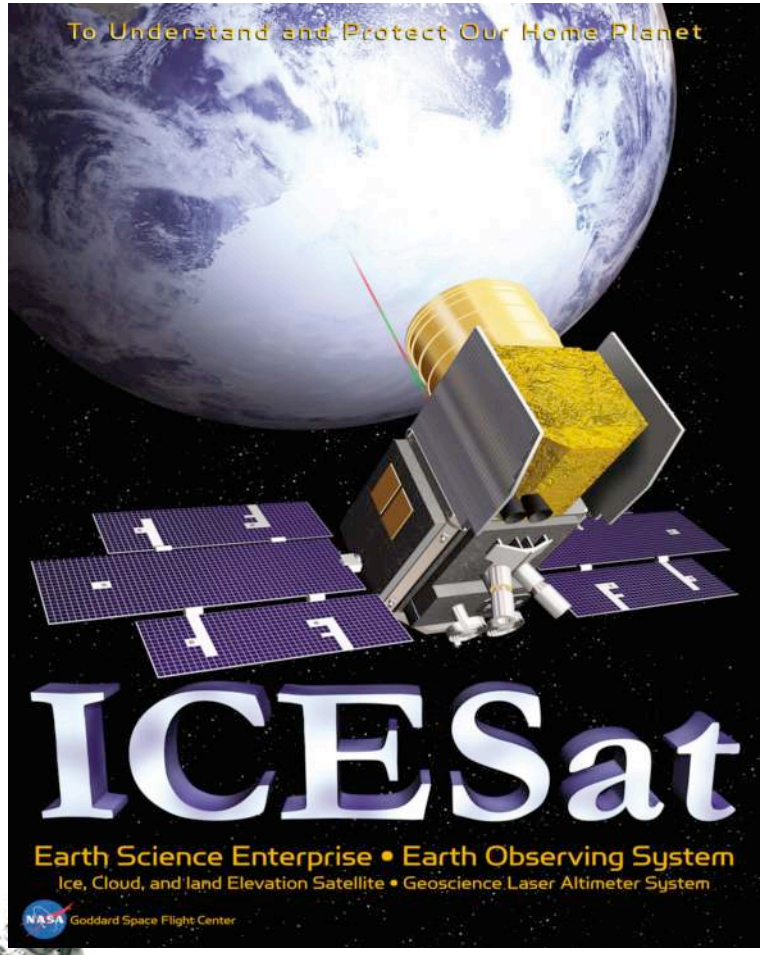
Space Based Lasers- Earth Sciences

ICESat



ICESat (Ice, Cloud, and land Elevation Satellite) is the benchmark Earth Observing System mission for measuring ice sheet mass balance, cloud and aerosol heights, as well as land topography and vegetation characteristics

Space Based Lasers- Earth Sciences

Carbon 3D

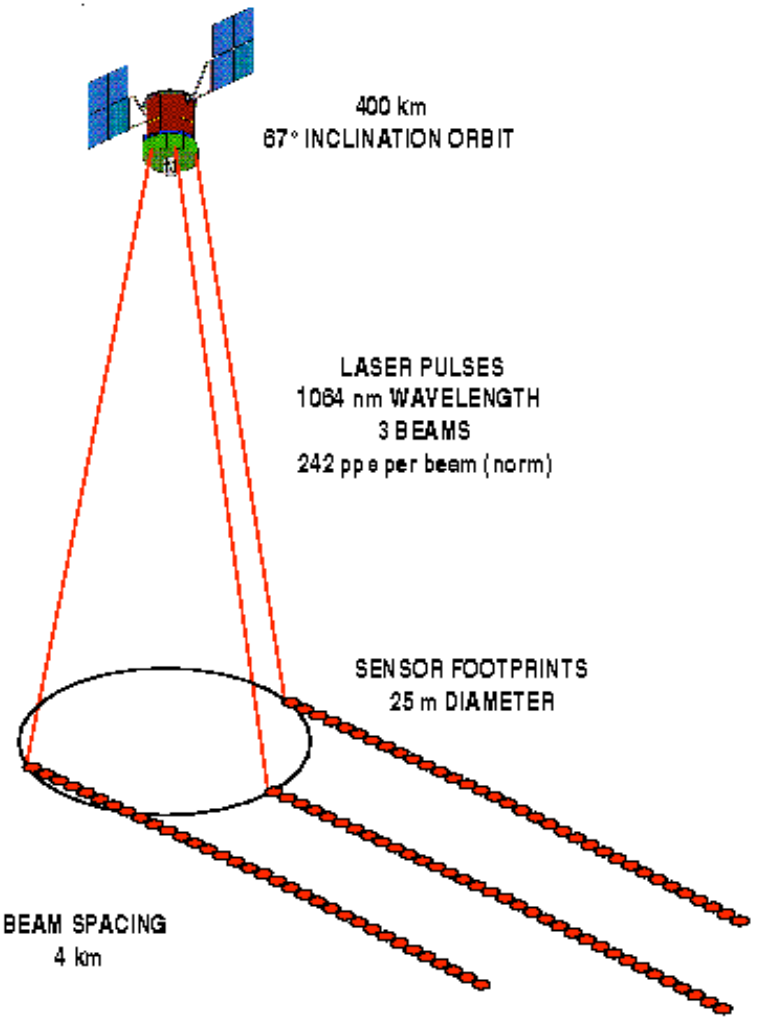
Science Objectives

Landcover Characterization for:

- ***Terrestrial ecosystem modeling, monitoring and prediction***
- ***Climate modeling and prediction***
- ***Global reference data set of topographic spot heights and transects***

Measurement Objectives

- ***Vegetation canopy top height ±1 m***
- ***Vertical distribution of intercepted surfaces***
- ***Ground Surface elevation ±1 m***
- ***Measurement transects globally gridded to 4 km X 4 km data products***

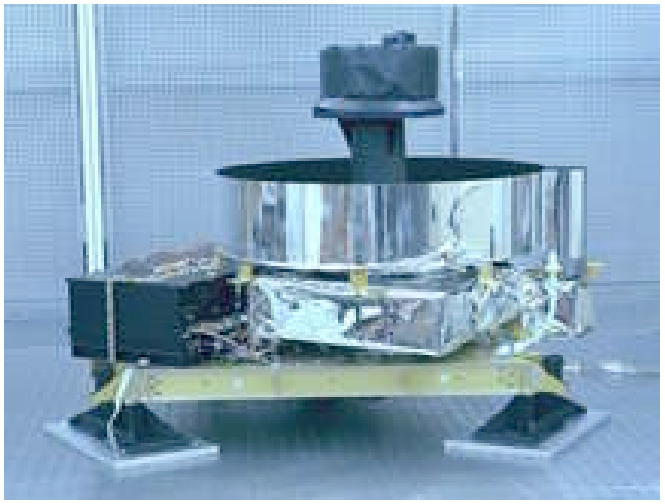


http://www.geog.umd.edu/vcl/INSTRUMENT.html

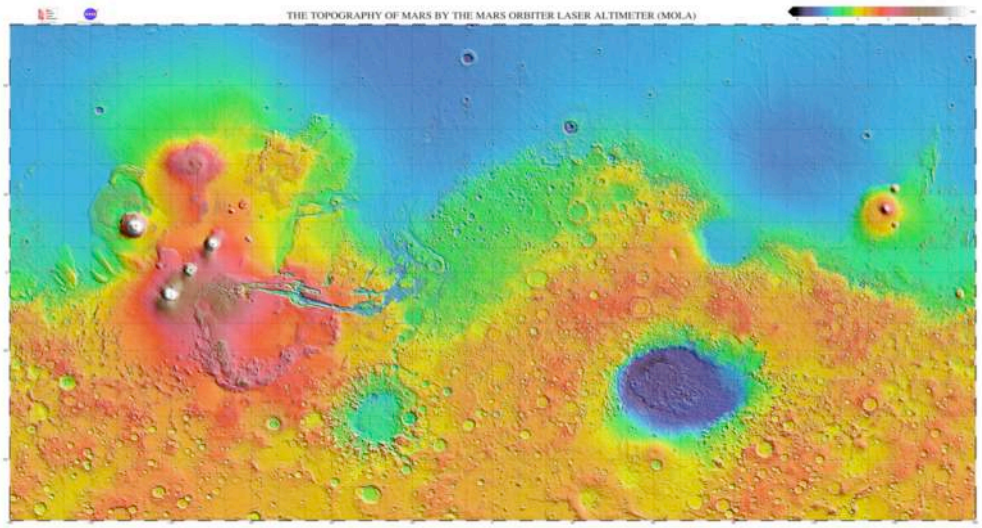
Space Based Lasers- Planetary Sciences

MOLA

The Mars Orbiter Laser Altimeter, is an instrument on the Mars Global Surveyor spacecraft. It collected altimetry data about the height of surface features on Mars until June 30, 2001.



http://mola.gsfc.nasa.gov/gifs/mola_instrument.jpg



http://mola.gsfc.nasa.gov/gallery.html

Space Based Lasers- Planetary Sciences

MLA

Mercury Laser Altimeter:
This instrument contains a laser that will send light to the planet's surface and a sensor that will gather the light after it has been reflected from the surface. Recording variations in this distance will produce highly accurate descriptions of Mercury's topography.

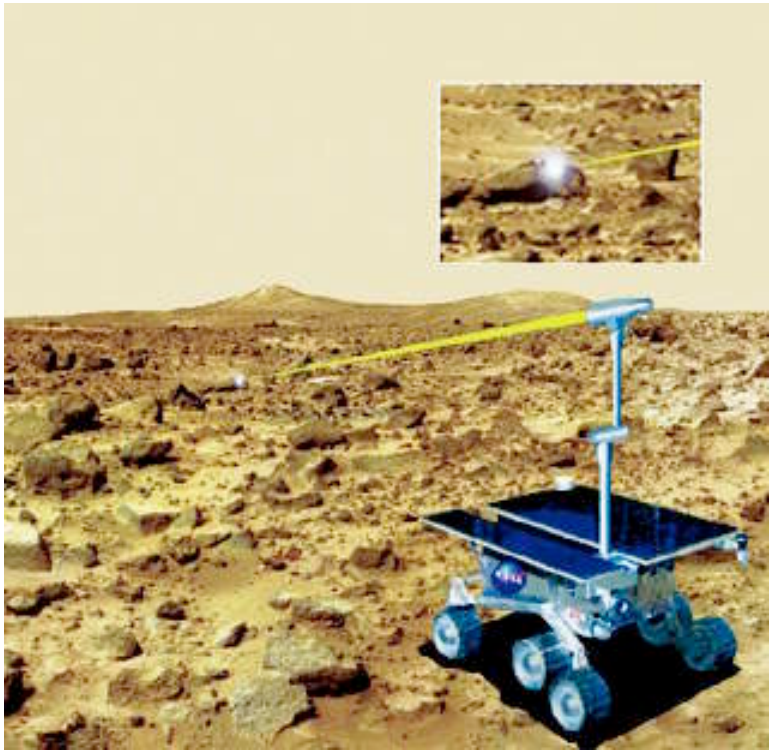
Space Based Lasers- Planetary Sciences

LIBS on the Martian Rover.

- A team in Chemistry Division is working with NASA to develop a method of elemental analysis for upcoming space missions.

The LIBS instrument is

- flexible and can quickly examine a large number of targets in difficult-to-reach locations, such as boulder fields or cliff faces.



http://pearl1.lanl.gov/external/LIBS/libs.htm

Space Based Lasers…

- **Can produce extraordinary data, unprecedented to date**
- **Can be used in versatile configurations for a variety of *active* remote sensing applications: Lidar, spectroscopy, etc.**
- **Are Challenging!**

Space Based Lasers- Contamination

Lasers Require Extraordinary Levels of Clean

- **Particulate contaminants on optics**
- **Molecular contaminants on optics**
  - MOLA II is what flew. MOLA I damaged during testing from silicone contamination.
  - GLAS damaged during testing from contaminants in system.
- **Molecular contamination in *atmosphere***

Space Based Lasers- Trace Atmospheric Contaminants

Previous Published Research:

Silicones in sealed system lead to catastrophic damage

Hydrocarbons in sealed system can lead to catastrophic damage…when no O_2 present!

- Work done in pure N_2 atmosphere…what about vacuum?
- Work done with various hydrocarbons…aromatics worst

Contamination in Sealed Lasers Experimental Objectives

Objectives

Test compounds in vacuum systems (also lacking O_2) look for unexpected onset of damage when exposed to laser at 1064, 532, 355 (eventually) nm.

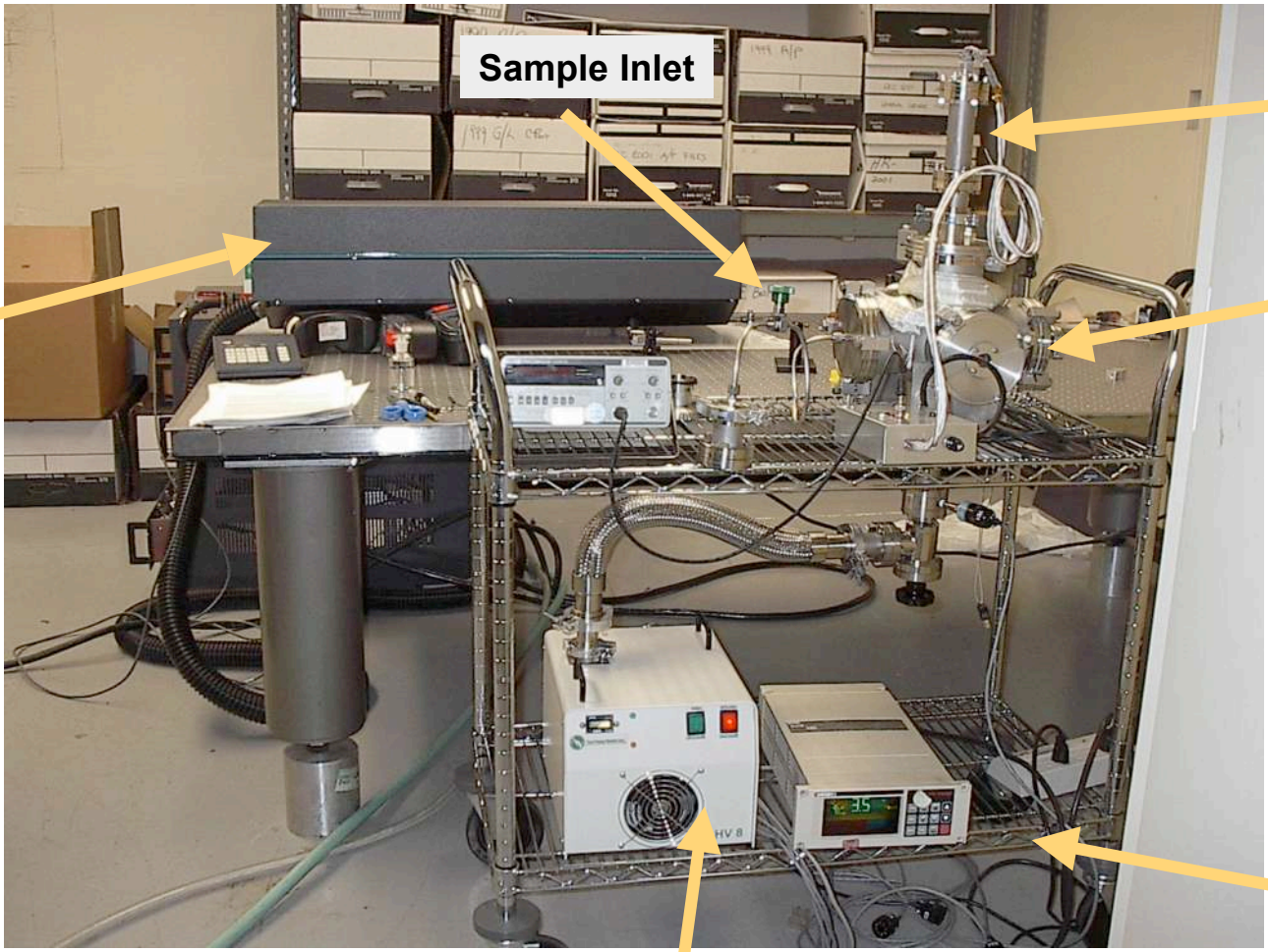
If positive results (damage occurs) then test the onset as a function of

- Contaminant concentration
- Laser Fluence

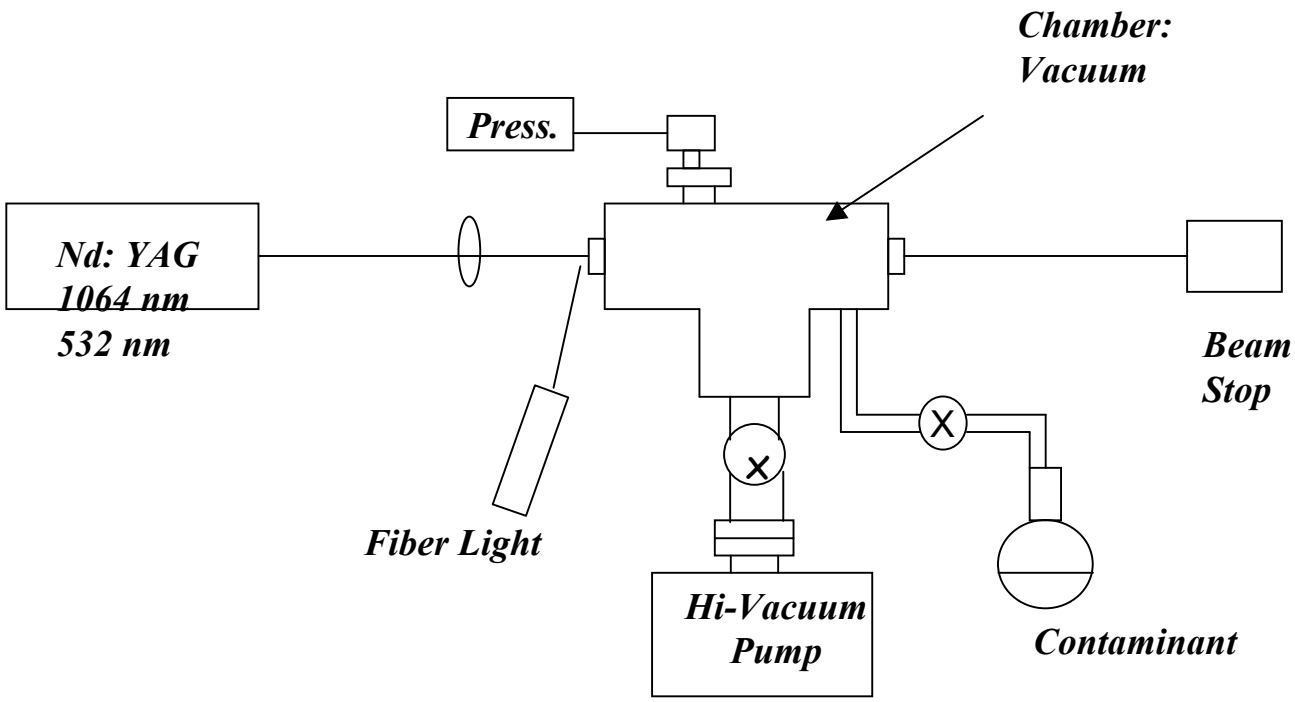
Identify compounds or outgassing products of concern vs. “safe”.

Identify mechanism for induced damage.

Experimental Set Up



Experimental Set Up



Experimental Set Up

Test Conditions:

Laser:
1064 nm
180 mJ/pulse (<20 ns pulse)
Beam diameter (at window): 5 mm
Fluence: 680-800 mJ/cm^2

System:
Vacuum<1.0x10^{-3} torr
Contaminant: 5x10^{-3}-1.2x10^{-1} torr
Pump & Hold type Experiment

Substrate(s):
Fused Silica 80/50 Polish
MgF_2 coated

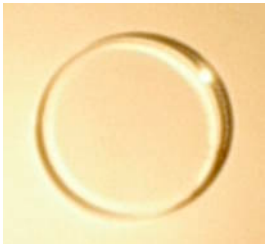
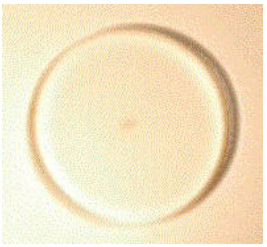
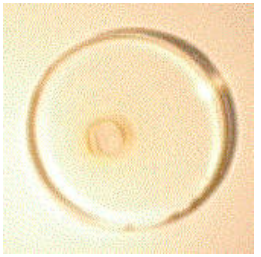
Baseline Conditions:

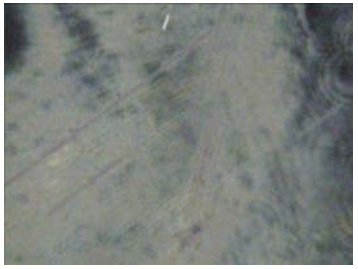
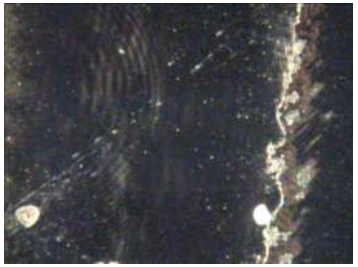
Fused Silica
- No damage prior to addition of toluene in ≥460K shots
- No damage to sample after system bakeout ≥ 720K shots

MgF_2 Coated
- No damage prior to toluene in ≥460K shots

Results: Toluene

vacuum

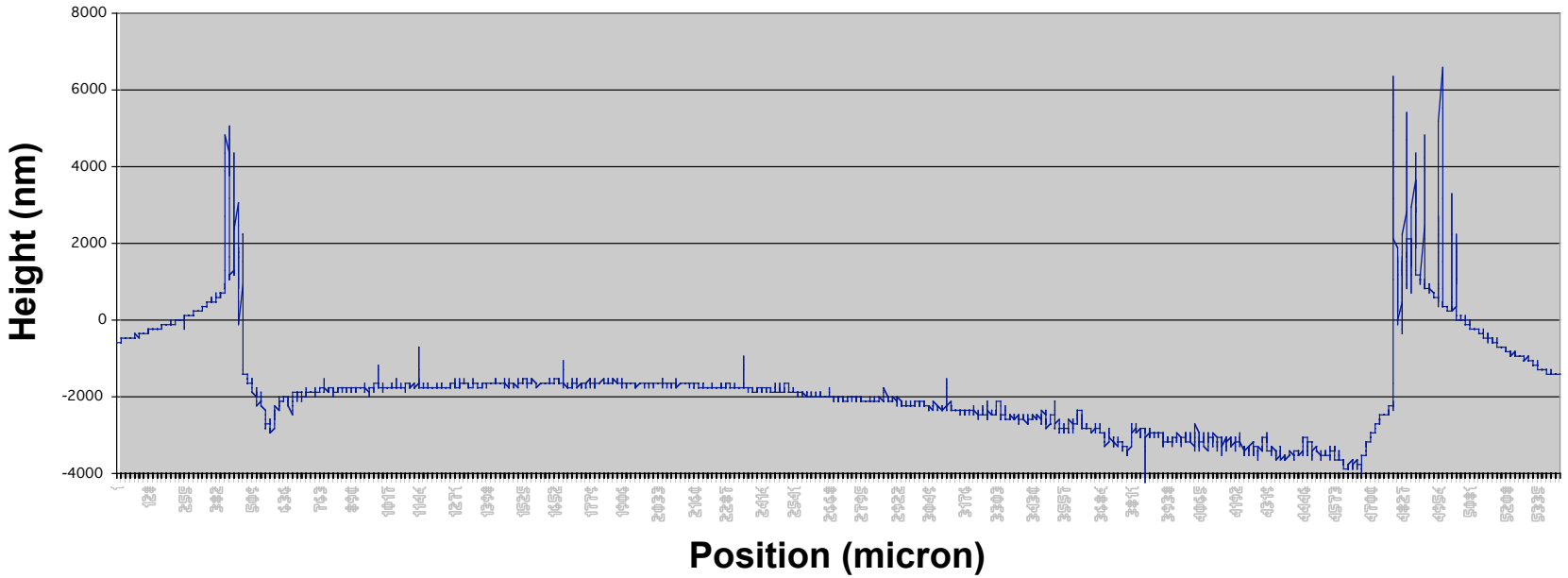
Onset of Damage	Moderate Damage	Severe Damage
		
P_{tol}=37mtorr	P_{tol}=50mtorr	P_{tol}=41mtorr
97K shots	93K shots	124K shots
Sample 13	Sample 20	Sample 29

			Perimeter	Center
100x				
200x				

Results: Toluene

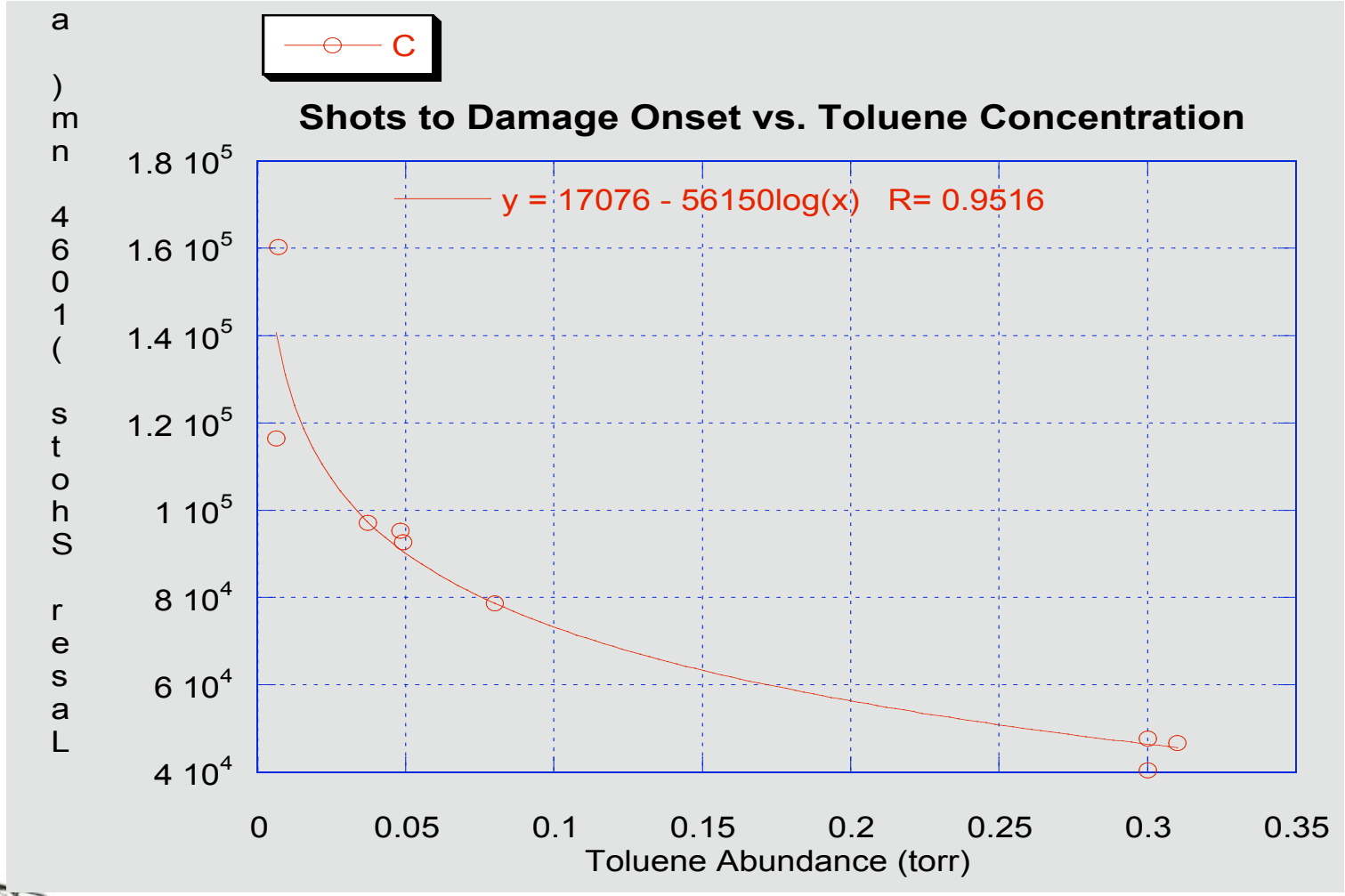
vacuum

Profile of SiO2 Optic Damage



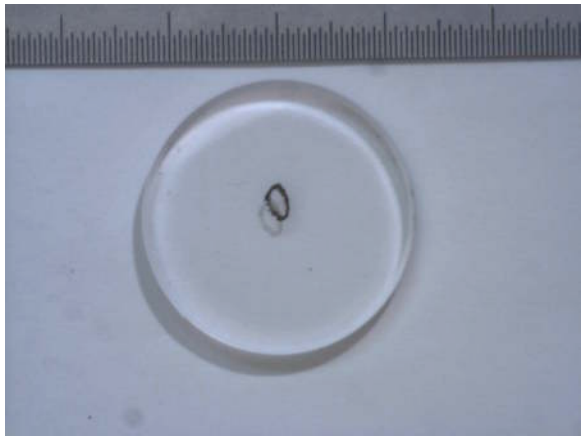
Results: Toluene

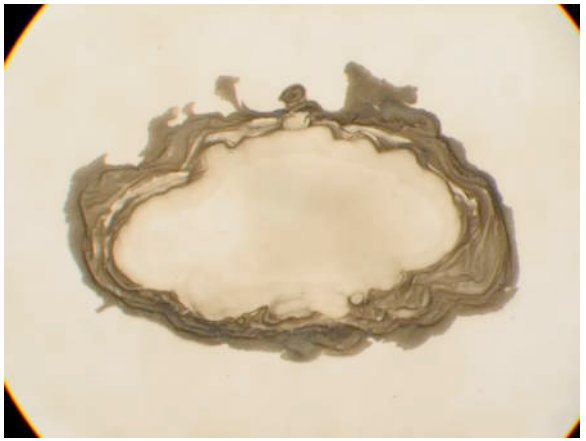
vacuum

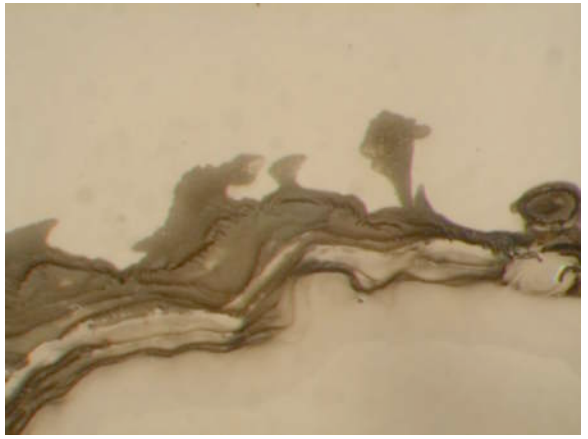


Results: Toluene

nitrogen



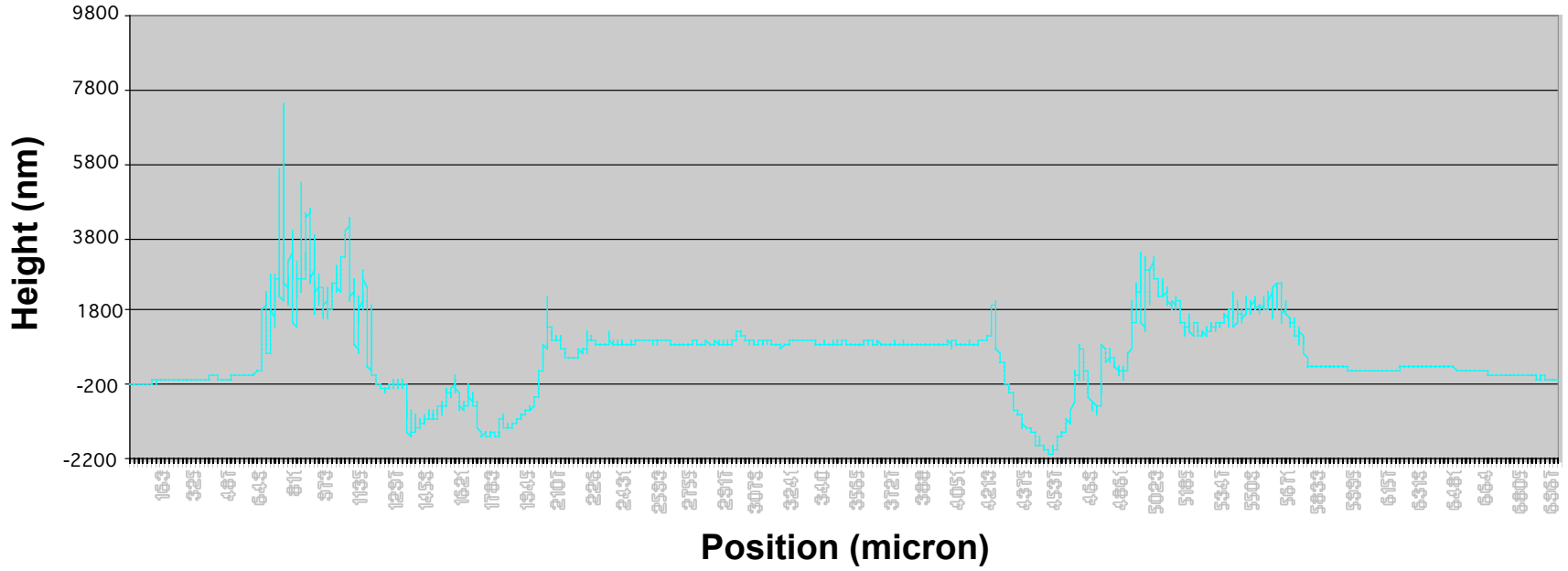




Results: Toluene

nitrogen

Profile SiO2 Damage toluene+N2



Position (micron)

Results: Other Materials

Acetone:

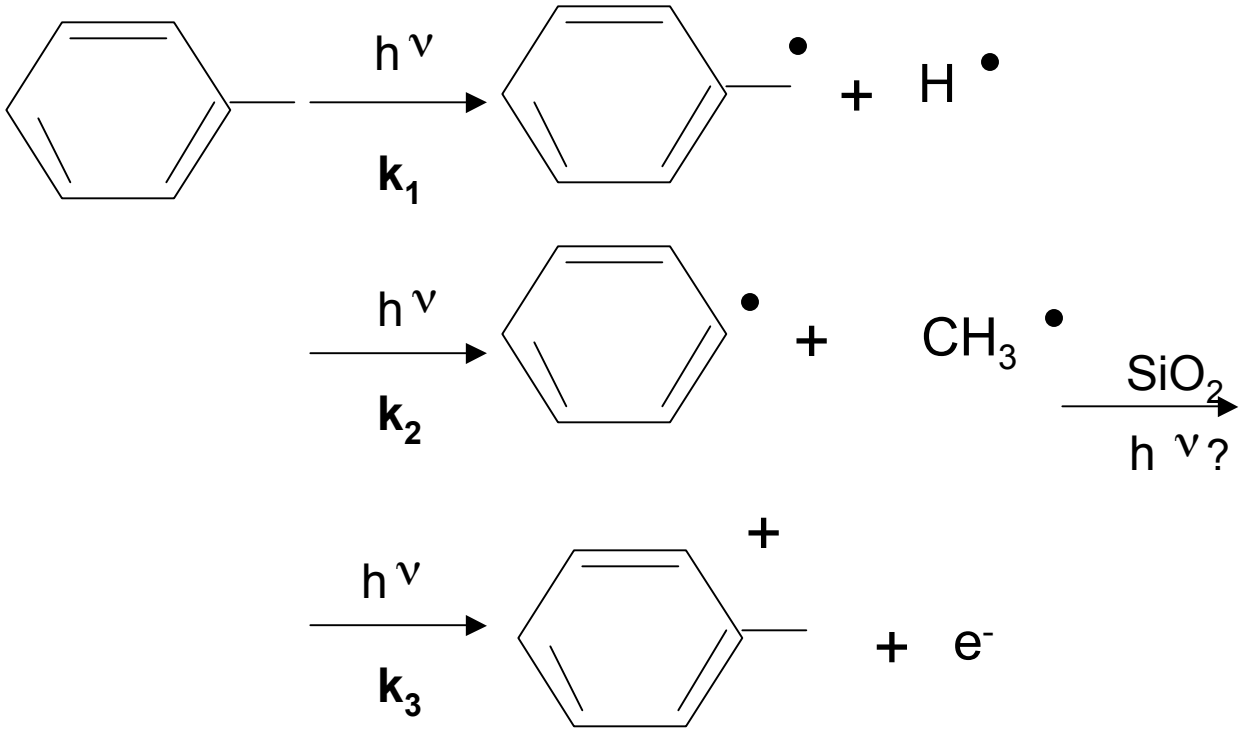
No damage in vacuum (Reported light damage in N_2)
711K shots; Acetone= .14 torr

NuSil CV 2946:

Heating to 40^o C, Effusive source directed toward window

Also to be tested:
IPA, Milbond adhesive, Scotchweld 2216

Possible Mechanism:
Toluene



Etc.

$k_{i(s)} > k_{i(g)}$

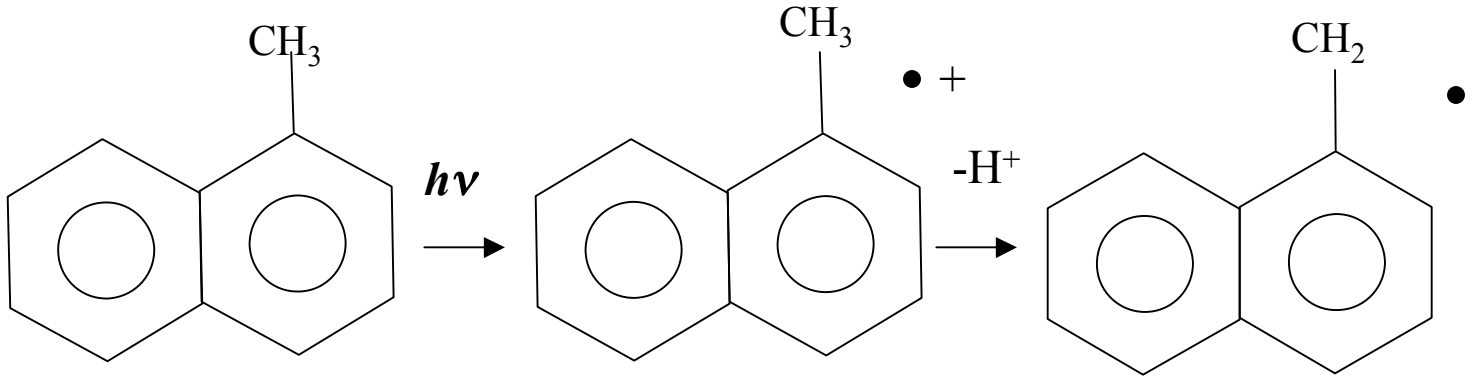
Possible Mechanism:
Toluene

Gas Phase Reactions Observed:

Squire and Bernstein, *J. Phys. Chem.* 88 (1984)
Frochtenicht, *J. Phys. Chem.* 102 (1995)

Surface Reaction Observed:

Dabestani and Sigman, Spectroscopy and Photochemical Transformations of Polycyclic Aromatic Hydrocarbons at Silica and Alumina-Air Interfaces." *Solid State and Surface Photochemistry*, V. Ramamurthy and K. Schanze, Eds., Marcel Dekker, (2000) .



Future Work

NuSil CV 2946:
Heating to 40^{o} C, Effusive source directed toward window

Determine relationship of damage to fluence (use higher fluences)

Investigate longer exposure times (>10^{8})

Use shorter wavelengths

Also to be tested:
IPA, Milbond adhesive, Scotchweld 2216

Acknowledgements

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Laser Risk Reduction Program